Polytechnic University of Catalonia

Master in Numerical Methods / Master in Computational Mechanics

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Communication Skills 1

Assignment 2: Extended Abstract

Carles Duñó Nosas
January 25, 2016

Project

STEEL BRIDGE LAUNCHING ANALYSIS WITH CORRUGATED WEB USING ADVANCED NUMERICAL SIMULATIONS by Carles Duñó

1. Introduction

In this paper, realistic nonlinear 3D simulations of incrementally launched steel bridge girders with corrugated webs are presented. The analysis accounts for three sources of nonlinearity: geometry, material and boundary conditions. The principal feature of this type of analysis is the realistic reproduction of the launching. The girder is fully assembled and then pushed longitudinally along the launching path. As the girder reaches intermediate supports, a full-contact formulation is activated and reactions are transmitted between both bodies. Reactions, displacements, stresses and strains are available throughout the launching process in every point of the girders. The simulations are presented in a twofold fashion since the generated data information may be exploited at both design and construction stages. For the former, the model provides predictive capabilities for inferring potential failure due to the combination of loads (bending, shear and patch loading altogether). For the latter, the results obtained are presented in a way that data may be used for planning a structural health monitoring (SHM) deployment. Relevant figures concerning results as well as detailed information concerning the numerical modeling of the process are provided.

Fig. 1: Example of the launching with corrugate webs

2. Steel bridge launching

The incremental launching method (ILM) is a bridge construction procedure in which the superstructure is set on an assembling yard, typically placed in one side of the landform to be crossed, and then pushed longitudinally towards its final position. The launching is typically performed statically in a series of increments from one side to another. It is estimated that thousands of concrete and/or steel bridges have been incrementally launched worldwide.

The ILM has gained popularity since it may guarantee minimal disturbances to the surroundings which may be of a great concern during construction. Careful analysis, though, is compulsory at design stages, since a thorough time-stepped solution is required. The process involves a continuous change of the structural schemes of the bridge with varying geometries, loads and boundary conditions. Furthermore, at construction stages, a considerably specialized construction equipment and expertise are needed. Figure 1 displays an example of the continuous change of the structural scheme in a steel girder which is incrementally launched.

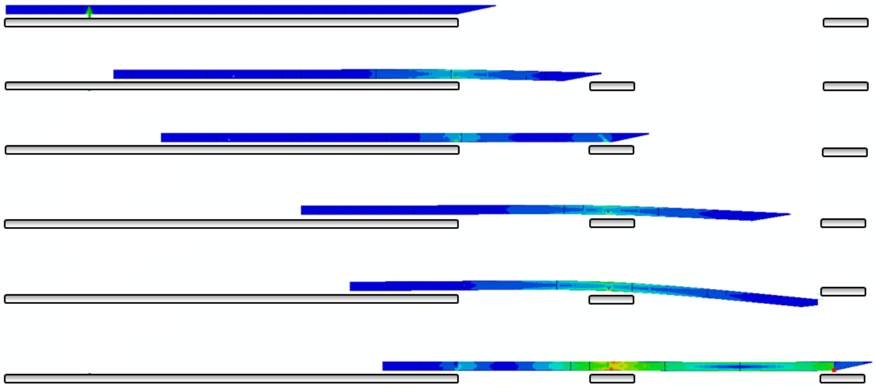


Fig. 2: Bridge launching in a steel girder with varying structural schemes.

Studies related to the analysis of the structural behavior of straight doubly-symmetric steel plate girders when launched are abundant. The girders are generally launched in pairs or in groups since these arrangements provide a considerable rotational stiffness. Lateral torsional buckling (LTB), patch loading and the interaction of bending, shear and concentrated forces are generally the most prominent conditions for the steel girders design. Bridge launching in which the steel girders are assembled with corrugated webs are also found and analyzed in the literature. The design is generally based upon the stress analysis (shear and secondary moment about the minor axis of the loaded flange M_z) on a discrete basis. The girders are analyzed at precise unfavorable points at which launching is expected to generate the worst case scenario. Theoretical approaches aimed at determining the non-uniform torsion of curved, incrementally launched girders have been recently launched but numerical analysis of such constructive process are not yet generalized in design offices due to, mainly, their computational cost and complexity associated.

3. Numerical Simulation

A FE-based numerical model is used as a simulation tool. The model is implemented in the commercial Software Abaqus-Simulia. The model reproduces realistically the movement of one steel girder over a launching platform towards the intermediate and end supports. This movement is applied through a large series of small increments. The size of the increment is a function of the total length of the girder (ranging approximately from L/1500 to L/3000). As a result, the incremental procedure is static but nonlinear. The bodies are simulated with shell elements. Shell elements allow developing 3D geometries realistically for cases in which one dimension is considerably smaller than the others. The material nonlinearity for metallic materials is based upon an ideal elastic-plastic constitutive equation. For multi-axial stresses, the uniaxial constitutive equation includes the von Mises criterion. Hardening is accounted for by including an isotropic formulation.

The boundary conditions are quite particular. The numerical model was expected to reproduce a multi-body physical problem that involved a mechanical interaction between the steel plate and the support conditions. The steel plate girders were modeled with first-order shell elements. The supports were modeled as analytical, rigid and frictionless surfaces on which the steel plates were able to slide and/or transmit contact stresses but conversely, were not able to penetrate through. These analytical surfaces were geometrically defined as objects rigidly connected to the ground.

The process consisted of a sequential movement (static) of the girder along a given path. In this particular case, the path is defined as a straight horizontal line but may also be defined as circular, for the case of horizontally curved bridges. The process encompasses full nonlinearity for the plate geometry, the material (elastic-plastic with isotropic hardening) and the boundary conditions (a contact-based formulation between bodies). Table 1 summarizes the numerical features of the performed simulations. The models were validated by comparing deflections, strains and vibrations with a scale-reduced test of a steel profile launched incrementally in the lab using both beam elements and shell elements.

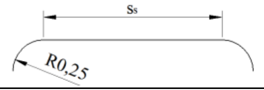
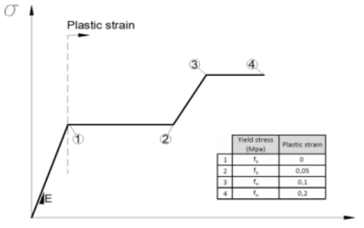
NUMERICAL SIMULATION			
Software	Abaqus 6.10	Interaction properties:	
Solver	Abaqus-Standard	· *Normal behaviour: No penetration and separation after contact*	
Procedure	Geometrically nonlinear	· *Tangential behaviour: Frictionless*	
Analized structure	Two spans (20 and 30 m respectively) bridge launching process	Bearing modelling	Analytical rigid surfaces
Cross-section	Transversally stiffened plate girder	Bearing shape	
Load	Only self-weight		
Material properties:		Constitutive equation	
· *Steel class*	*S355*		
· *E (N/mm²)*	*210000*		
· *Poisson ratio*	*0,3*		
· *Density (kg/m³)*	*7850*		
· f_y *(N/mm²)*	*355*		
· f_u *(N/mm²)*	*490*		

Table 1. Numerical features of the performed simulations.

4. Incremental launching in steel I-girder with corrugated webs.

The main subject of analysis corresponds to the case of the web girder is corrugated. The focus of the analysis was on the understanding of the interaction of stresses and the moment distribution on the web, not only for the worst-case scenario that has been studied in last decades but also, for travelling loads during launching. Detailed analysis of the investigation is given in. A model of a monotonically increasing web-corrugated panel loaded up to failure and found in was developed for calibration purposes.

Figure 3 displays the evolution of the von Mises stresses in web panels for travelling loads when reaction moves from one stiffener to another. It is worth pointing out how the load generates stress distributions in accordance with the web corrugation. Expectedly, the magnitude and sign of the generated moment distribution may be inferred. Furthermore, Fig. 4 shows the vertical displacement of the launching nose during construction (a typical magnitude measured in SHM deployments).

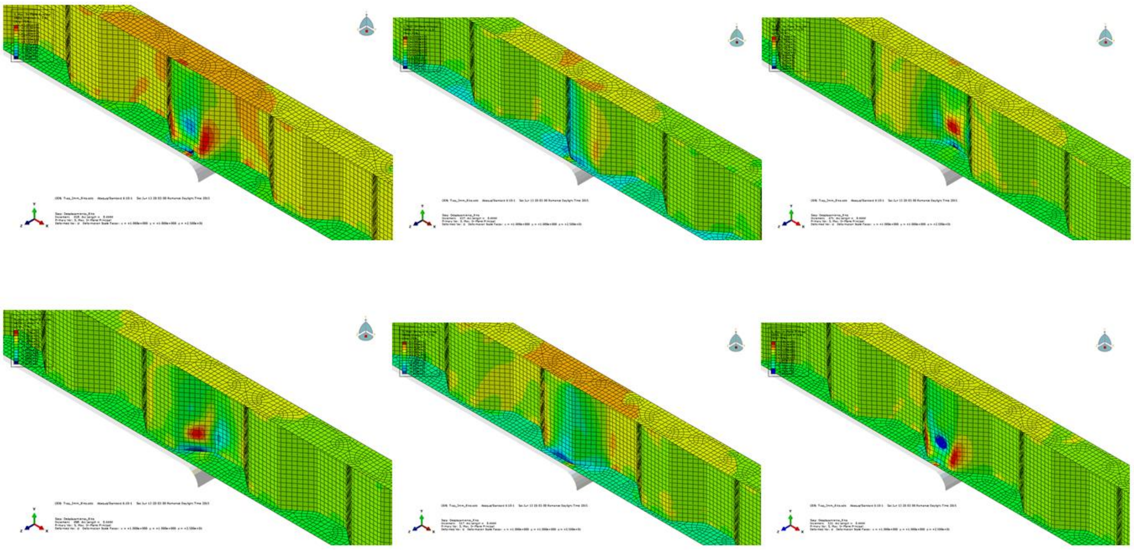


Fig. 3: Von Mises stresses in the directly loaded panel as the reaction is introduced variably.

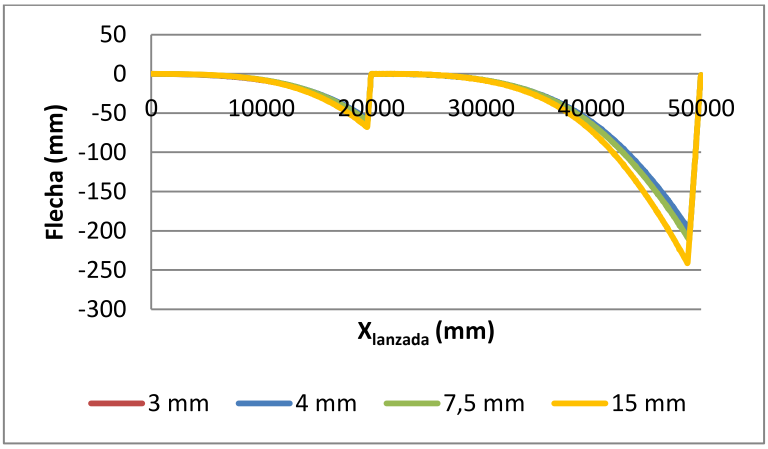


Fig. 4: Vertical displacement in a node located at the web panel.